Understanding the Physical Properties of the Kilauea Volcano by Analyzing Long-Period Volcanic Earthquakes

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Abstract:

Long-period (LP) volcanic earthquakes are a vital resource in volcano seismology. These events are associated with deformational changes and the dynamics of volcanoes that lead to predictions of seismic hazard events. This project performs an analysis of low-frequency events during the 2018 Kilauea caldera collapse and eruption in the East Rift Zone. To investigate the area, we analyzed the vertical components of over 76,324 P waveforms across 100 stations. We then calculated the frequency index (FI) for each event and examined spectrograms to determine the type of seismic event, separating them by high and low-frequency energy. We considered FI values <-0.51 to be low-frequency events while classifying events with FI values >-0.30 as high frequency. Hybrids events were found between the range of lower and high frequency. By classifying LP events during 2018 and looking at their spatial and temporal distribution, we can better understand the behavior of magma during the sequence.

Background & Motivation:

- Kilauea Volcano has been active for around 200 years; it is one of the the most active volcanoes in the world.
- During 2018, there was a connection of outflow of lava in the lower east rift zone and the caldera collapse.
- Caldera formation can be triggered by magma withdrawal to feed violent explosive eruptions or by the intrusion of magma into the surrounding rock, sometimes providing long-lived effusive lava flows (Anderson et al., 1).
- Changes in the magma system in the middle of the rift zone are related to ground deformation and seismicity that indicated down rift intrusion of a dike.
- Long period (LP) or low-frequency events are valuable insight for volcanic seismology process.
  - LP events are related with fluid motion, such as magma, gases or hydrothermal fluids.
  - Low-frequency events are used as a reference to study features such as frequency rates or the behavior or magma during the sequence.

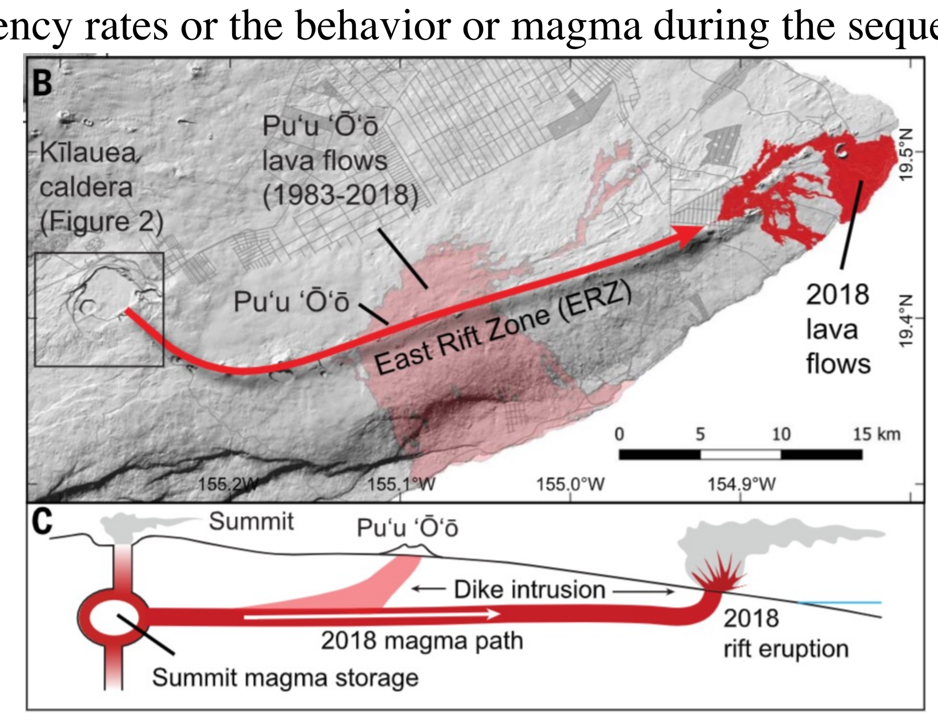


Figure 1. B) Shows the eruption of 2018, where magma flowed 40km away underground from Kilauea caldera to the Lower-East-Rift-Zone. C). Shows a not scale section of the magma path from the summit to LERZ.
Anderson et al., Science 366, eaaz1822(2019)

Methods:

- Analyzed the Matoza catalog to obtain data from all the events registered in 2018.
  - Around 76,324 earthquakes events were found across 100 stations.

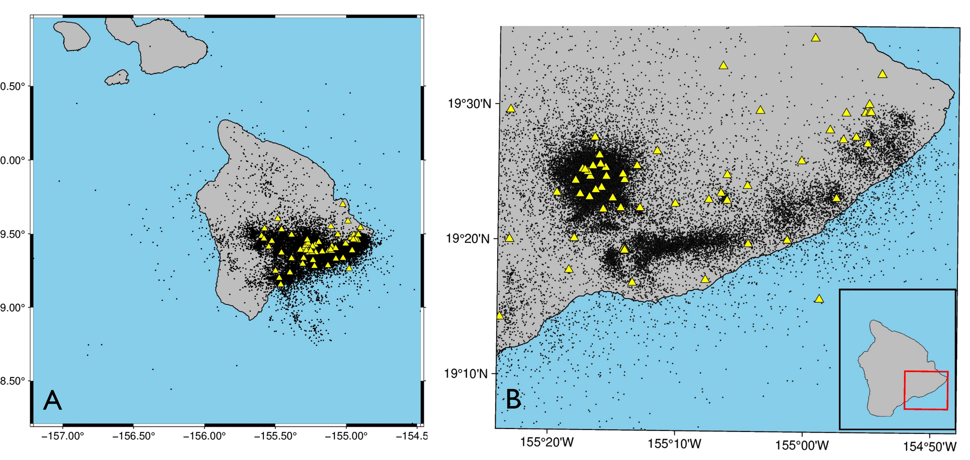


Figure 2. A). Shows the total seismicity at the Big Island, Hawaii in 2018. B). Shows the seismic activity in lower East-Rift-Zone(ERZ). Black dots represents earthquakes and yellow triangles are the stations.

- Used filtered data by bandpassing from 2.0-16.0Hz.
- Calculated the signal-to-noise ratio (SNR) to avoid unnecessary noise
- Calculated the frequency index (FI) to separate each event by low-frequency and high-frequency energy. The following formula was used:

$$FI = log_{10}\left(\frac{mean(A_{upper})}{mean(A_{lower})}\right)$$

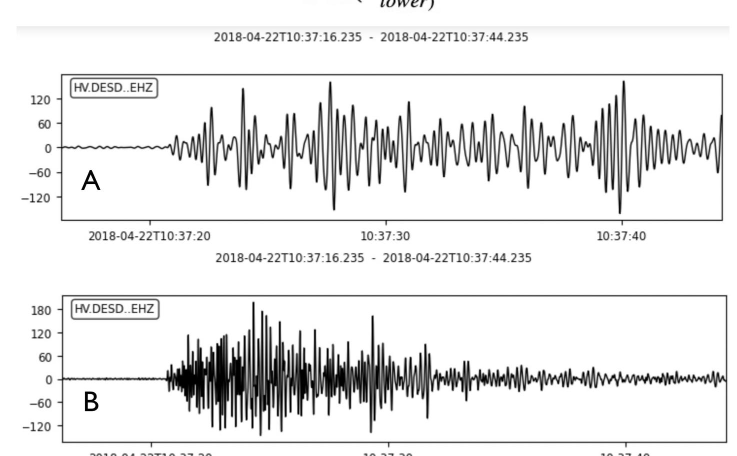
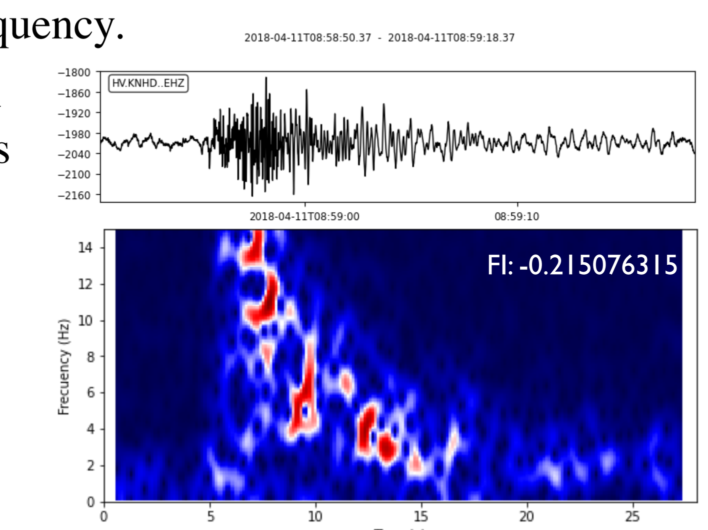


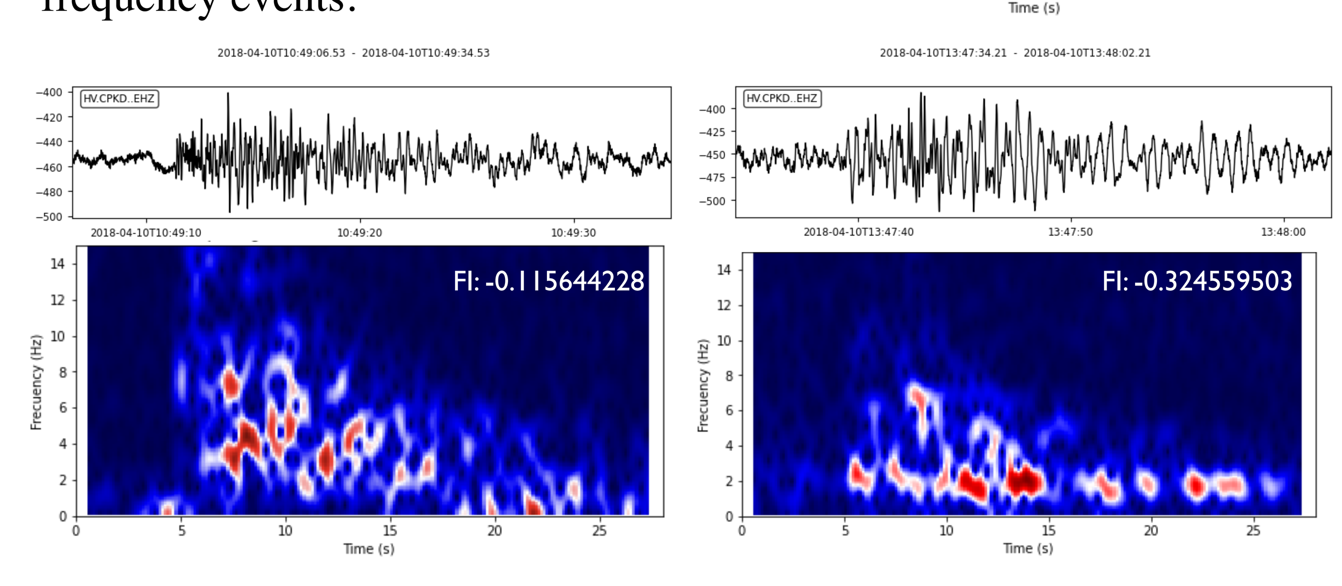
Figure 3 A). Shows low filtered data from 2.0-4.0 Hz.

B). Shows high-filtered data from ranges between 5.0-16.0Hz.

Results:

- Frequency index (FI) allowed us to classify the event by high-frequency or low-frequency energy. It also let us measures each volcanic earthquake by separating them into three groups such as hybrid, low-frequency, high-frequency.
- According to our result we found FI less than -0.51 are classified as low-frequency or LP events. Values greater than -0.30 correspond to events referred as high-frequency or volcano tectonic. Hybrid events were found in between high and low frequency events.





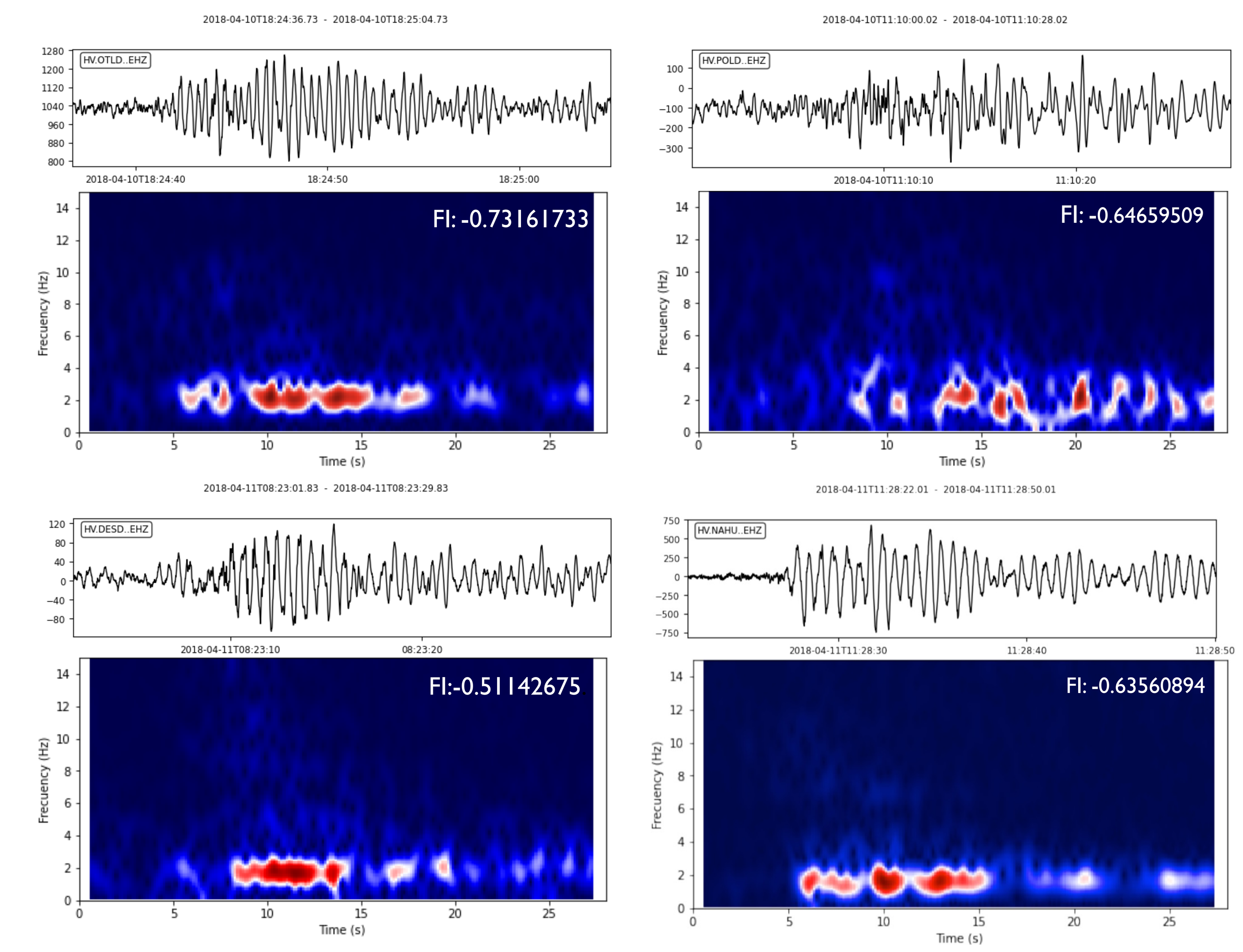


Figure 4. Shows the seismogram (top) and spectrogram (bottom) for each LP. It also shows the FI value for this type of earthquake. The spectrogram shows the energy (red) that it is related with ground motion.

Conclusion:

- FI allows us distinguish any long-period event occurred in 2018. We believe that this type of earthquakes are associated with magma movement that is rising from magma chamber (as proposed by Buurman and West, 2006). LP are useful in analyzing the fluid changes and the internal behavior of a volcano. Low-frequency events started to be present in the month on April 10th.
  - The application of low-frequency events allow us to have better understanding of the physical process and the state of the volcano, which it led to predict any hazard events.
  - For future work, we will try to analyze and compare any swarm events, that it will allows to understand the state of the volcano before the eruption.

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